Flexible, Lightweight Quantum Dot Solar Cells Using Plasmonic-Enhanced Light Absorption

Completed Technology Project (2013 - 2017)

Project Introduction

Solar cells, or photovoltaic cells, are critical to NASA operations due to the abundance and availability of solar power. Current photovoltaic technology is based on bulk semiconductor wafers, which are typically non-conformal. In contrast, flexible, lightweight solar cells can be incorporated on to the surfaces of rovers and habitats. This can be used to generate auxiliary power that can power additional sensors or extend the battery life during space exploration. This research proposes the fabrication of solar cells that are conformal and inexpensive, and can be adhered to a variety of surfaces that were previously unsuitable for photovoltaic technology. The objective of this research proposal is to fabricate the first flexible, efficient, quantum dot solar cell. The nanoscopic quantum dots are critical to this device because of their enhanced optical properties and solution-processability. Solution-processability reduces the required material because thin semiconductor quantum dot films can be deposited using low cost methods, such as inkjet printing. Not only does this reduce the weight and cost of the device, but it also enables the use of flexible and conformal substrates. Thus, solution-processable quantum dots can improve the optical efficiency, reduce the weight and cost, and enable flexible and conformal devices. As a trade-off, additional plasmonic-enhanced light absorption techniques will be required to achieve high power conversion efficiencies. This plasmonic-enhanced light absorption requires metal nanoparticles to scatter and concentrate light in the solar cell. Using nano-scale structures can improve solar cell power conversion efficiency in a lightweight, flexible device. To achieve the optimal design configuration, the quantum dot films must be fabricated and characterized. Once the quantum dot film can be quantified in electrical and optical terms, the device performance can be modeled. In particular, modeling of optical behavior is performed by finite-difference time-domain (FDTD) simulation software, whereas electronic behavior is modeled using a solar cell simulation tool, PC1D. Since many of the device parameters are inter-related to the device performance, both electronic and optical simulation results must be used to optimize all of the device parameters. After optimization, an efficient, flexible, lightweight quantum dot solar cell can be fabricated. In addition to improving photovoltaic technology, research in this field can advance the understanding of nano-scale device design. These quantum dots contain approximately 100 to 100,000 atoms and behave very differently from their macroscopic counterparts. Since many of the properties observed at this nanoscopic scale are governed by the principles of quantum mechanics, on-going research must relate nano-scale phenomena to macroscopic behavior. Both experimental and simulation techniques are used in this research proposal to relate theory of nano-scale phenomena into a real-world, functional device.

Anticipated Benefits

This research includes the fabrication of solar cells that are conformal and inexpensive, and can be adhered to a variety of surfaces that were previously

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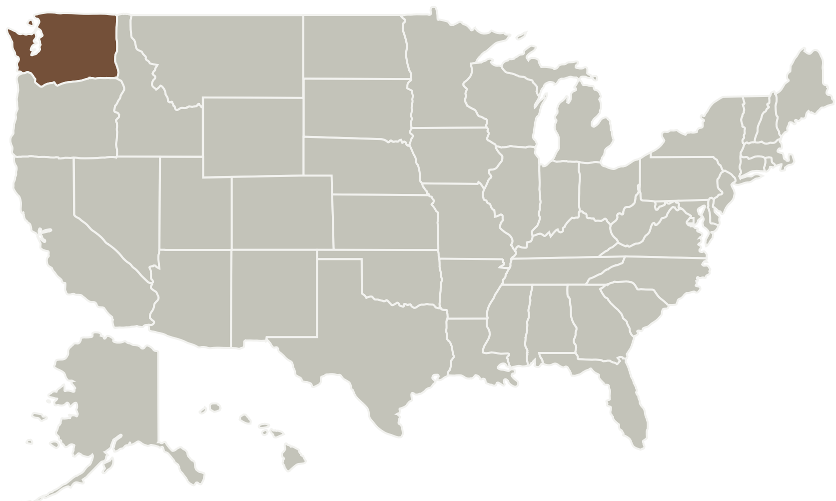
unsuitable for photovoltaic technology. The objective of this research proposal is to fabricate the first flexible, efficient, quantum dot solar cell. The nanoscopic quantum dots are critical to this device because of their enhanced optical properties and solution-processability.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Washington University in St Louis	Lead Organization	Academia	Saint Louis, Missouri

Primary U.S. Work Locations
Washington

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

Washington University in St Louis

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

Lih Lin

Co-Investigator:

Erin M Sanehira

Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **3**

1 2 3 4 5 6 7 8 9

Applied Research | Development | Demo & Test

Technology Areas

Primary:

- TX03 Aerospace Power and Energy Storage
  └ TX03.1 Power Generation and Energy Conversion
    └ TX03.1.1 Photovoltaic

Target Destinations

The Moon, Mars, Others Inside the Solar System